

Watershed Monitoring for the Northwest Forest Plan

Data Summary Interpretation 2006 West Cascades Province

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INTRODUCTION

The Aquatic and Riparian Effectiveness Monitoring Program (AREMP or the monitoring program) is a multi-federal agency program designed to assess the effectiveness of the Northwest Forest Plan's Aquatic Conservation Strategy (USDA, USDI 1994) in maintaining or restoring the condition of watersheds in the Plan area. To evaluate the effectiveness of the strategy, the monitoring program determines whether key processes that maintain aquatic and riparian habitats are intact (Reeves et al. 2004). This information is used to assess the current condition of watersheds and to monitor changes in condition through time.

The Northwest Forest Plan was designed to account for the complex and dynamic nature of aquatic ecosystems resulting from the wide range of physical characteristics, natural disturbance events, and climatic features of the region (Benda et al. 1998, Naiman et al. 1992). Consequently, the assumptions underlying the monitoring program are that watersheds are dynamic systems that will not remain in a static condition indefinitely. Nor do we expect all watersheds to be in good condition at any one time (Naiman et al. 1992, Reeves et al. 1995). The primary product of the monitoring program is a distribution that describes the range of conditions of watersheds in the Plan area. Implementing the strategy should result in a range of watersheds conditions across the landscape that represents the natural range of conditions expected in a well-functioning aquatic network. If the strategy is effective, then the overall condition of watersheds across the region should either remain the same as it was when the strategy was implemented in 1994, or it should improve.

Watershed condition is evaluated at the USGS 6th-field hydrologic unit subwatershed (hereafter referred to as watershed) scale using a province-specific decision support model that aggregates data on in-channel, riparian and upslope attributes. These attributes are indicators of watershed processes. A watershed is defined as being in "good" condition if the physical attributes are adequate to maintain or improve biological integrity, with a focus on diversity and abundance of native aquatic and riparian-dependent species, salmonids in particular.

The purpose of this report is to provide local units with the results of our data collection and decision support modeling efforts for watersheds surveyed in the West Cascades physiographic province (Table 1). Separate reports were prepared for each physiographic province. Included in this report are overviews of field (in-channel) data collection methods and calculations performed on the data, GIS data collection methods, the decision support model used to evaluate watershed condition, and a guide on how to interpret the model results. Watershed-specific summary tables, maps, photos, raw field data files and GIS data accompany this report on the AREMP website. Benthic macroinvertebrate samples were collected in the field. These samples from some of the watersheds are currently at the laboratory being analyzed and were not available to be included in this report or the model output. Links to additional documents pertaining to the monitoring program and decision support models are available on the website.

Table 1. Watersheds sampled in the West Cascades Province 2002-2006.

USGS HUC	Watershed Name	Administrative Unit
170900020201	TABLE MOUNTAIN	EUGENE BLM
170900020304	MIDDLE UPPER COAST FORK WILLAMETTE RIVER	EUGENE BLM
170701051002	BIG LAVA BED FRONTAL CREEK	GIFFORD PINCHOT NF
170800020102	TWIN FALLS CREEK	GIFFORD PINCHOT NF
170800020108	ALEC CREEK	GIFFORD PINCHOT NF
170800020203	ELK CREEK	GIFFORD PINCHOT NF
170800020401	UPPER SIOUXON CREEK	GIFFORD PINCHOT NF
170800040302	WILLAME CREEK	GIFFORD PINCHOT NF
171100150110	LITTLE NISQUALLY RIVER	GIFFORD PINCHOT NF
171003070601	WEST FORK TRAIL CREEK	MEDFORD BLM
171100140104	UPPER WHITE RIVER/SILVER CREEK	MT BAKER/SNOQUALMIE
171100140202	CLEARWATER RIVER	MT BAKER/SNOQUALMIE
170800010102	DRAW CREEK	MT HOOD NF
170800010201	STILL CREEK	MT HOOD NF
170800010504	CEDAR CREEK	MT HOOD NF
170900110201	CUB CREEK	MT HOOD NF
170900110301	UPPER OAK GROVE FORK CLACKAMAS	MT HOOD NF
171003070402	CLARKS FORK CREEK/FOURBIT CREEK	ROGUE RIVER NF
170900090503	UPPER MOLALLA RIVER	SALEM BLM
170900020101	LAYNG CREEK	UMPQUA NF
171003010301	WARM SPRINGS	UMPQUA NF
171003010402	BEAR CREEK	UMPQUA NF
171003010801	STEAMBOAT HEADWATERS/CITY CREEK	UMPQUA NF
171003011101	LITTLE RIVER HEADWATERS	UMPQUA NF
171003011104	EMILE CREEK	UMPQUA NF
171003020302	DUMONT CREEK	UMPQUA NF
171003020403	DREW CREEK	UMPQUA NF
170900010106	UPPER MIDDLE FK WILLAMETTE/ECHO CREEK	WILLAMETTE NF
170900010303	LOWER SALT CREEK	WILLAMETTE NF
170900010504	MIDDLE FORK WILLAMETTE/LARISON CREEK	WILLAMETTE NF
170900010603	NORTH FK OF MIDDLE FK WILLAMETTE/FISHER CREEK	WILLAMETTE NF
170900010902	FALL CREEK/HEHE CREEK	WILLAMETTE NF
170900040102	FISH LAKE CREEK	WILLAMETTE NF
170900040201	UPPER SEPARATION CREEK	WILLAMETTE NF
170900040501	QUARTZ CREEK	WILLAMETTE NF
170900050107	BOULDER CREEK	WILLAMETTE NF
170900050503	GOLD CREEK	WILLAMETTE NF
170900060401	UPPER QUARTZVILLE CREEK	WILLAMETTE NF
170900060503	SIXES CREEK	WILLAMETTE NF

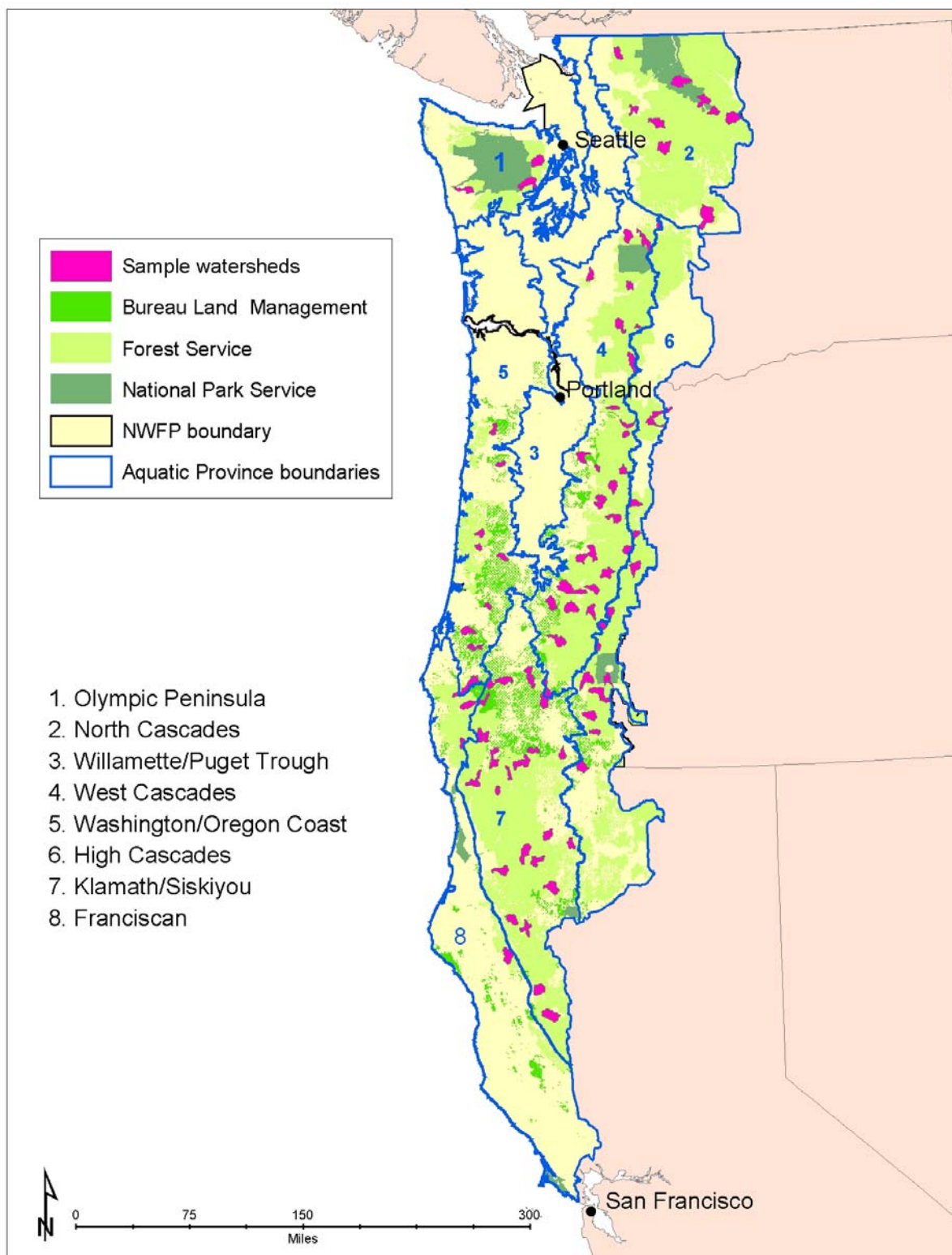


Figure 1. Randomly selected watersheds sampled 2002-2006 by the aquatic and riparian effectiveness monitoring program.

NEW IN 2006

Future direction for the monitoring program

Following the 10-year evaluation of the Northwest Forest Plan, the RIEC directed AREMP staff to develop options for modifying the monitoring program to meet the following objectives: provide information on the status and trend of watershed condition at different spatial scales, ranging from the Forest/BLM administrative unit to the entire Plan area, while operating under a constrained budget; work with PIBO monitoring program personnel to evaluate watershed condition consistently across Oregon and Washington by using common field protocols, a similar selection mechanism for sample sites, and decision support models to assess watershed condition; and standardize protocols and sample designs in order to share data with other state and federal agencies.

Provide information on the status and trend of watershed condition at different spatial scales – To address providing information at multiple scales, AREMP personnel developed a Geographic Information Systems (GIS)/remote sensing-based monitoring program option that relies on continued field sampling to inform GIS analyses. This option would allow the program to evaluate every watershed with more than 25 percent federal ownership in the Plan area as frequently as data are collected or updated.

The GIS/remote sensing-based monitoring program option, tentatively approved by the RIEC (3/17/06), is based on using decision-support models to aggregate in-channel, upslope, and riparian attributes and calculate a watershed condition score. In-channel physical, chemical, and biological attributes are measured in the field at randomly chosen sites within randomly chosen watersheds throughout the Plan area; upslope and riparian attributes are measured for every watershed using GIS and remote sensing data.

In-channel & upslope relationships

AREMP is implementing a GIS/Remote sensing-based option that relies on upslope and riparian indicators as surrogates for watershed condition to address manager's requests. The GIS/Remote sensing-based option is based on a "double sampling" design consisting analyses of upslope and riparian indicators (roads, vegetation, and landslides) in all watersheds in the Plan area (using GIS and remote-sensing data) combined with field sampling in a subset of watersheds. Condition in each watershed will be determined using a decision support model. A distribution of watershed condition scores will be produced based on data from every watershed in the Plan area. Such distributions are useful because they represent the full range of variability in the study area. Changes in watershed condition will be represented by changes in the distribution. As we implement this alternative, we will work toward developing relationships among the upslope and riparian attributes (e.g., vegetation, roads, and landslides) and in-channel conditions. When the relationships are developed, these upslope and riparian attributes will be used as surrogates for watershed condition. Field data are used to validate the relationships and ensure that the model results accurately reflect conditions on the ground.

The monitoring program has contracted with researchers for a one year project (Oct. 1, 2006 through Sept. 30, 2007) at both the Pacific Northwest Research Station in Corvallis and Oregon State University to develop the relationships between upslope/riparian and in-channel conditions. There are two goals for the project. First, we want to develop upslope/riparian and

in-channel relationships in order to use existing GIS data to predict in-channel conditions in non-sampled watersheds. Secondly, if relationships are successfully developed, then we will evaluate the variance structure of the predicted in-channel conditions and recommend how to allocate field samples, i.e., how to best balance the number of sites sampled within watersheds with the number of sampled watersheds.

The monitoring program adopted the first phase of the “universal sample design” for stream reach selection (based on the Generalized Random Tessellation Sampling design; see Stevens and Olsen 2003, 2004 for more information) developed by statisticians at the US EPA – National Health and Environmental Effects Research Laboratory. This selection mechanism is an extension of the previously used selection mechanism; however, it allows the monitoring program to share data with any other program using the same selection mechanism.

Wolf Creek Partnership

The monitoring program partnered with the Roseburg BLM to provide stream-channel monitoring for a multi-partner stream habitat restoration project. Wolf Creek, on the lower Umpqua River, is believed to be one of the most productive stream systems for coho salmon historically. Therefore, it was targeted for restoration activities. As a result, the Roseburg BLM Fisheries program funded the monitoring program to conduct sampling to determine the baseline or pre-restoration condition of the watershed. We used our existing field protocols and the statistical site selection so the data collected at the 41 sites will also support the monitoring programs’ goal of monitoring watersheds in the Plan area. Restoration work is scheduled for summer of 2007 and a revisit to the monitoring sites is scheduled for 2011.

Decision support models

Program personnel have been working with specialists on the Okanogan-Wenatchee and Colville National Forests and with the forests in the Blue Mountains (Umatilla, Malheur, and Wallowa-Whitman) to apply decision support models in their forest plan revisions. AREMP’s watershed condition model is being used by these forests as part of the key watershed designation process. Decision support models are also being used to conduct a sustainability analysis for aquatic focal species, e.g., fishes listed as “threatened” or “endangered” under the Endangered Species Act or are a species of concern. Key watershed determination and the sustainability analysis are requirements of a new proposed Aquatic and Riparian Conservation Strategy that will be applied across Oregon and Washington (US Forest Service Pacific Northwest Region). The new strategy will be part of each forest’s plan, and will replace previous management plans such as the Northwest Forest Plan, PacFish, and InFish.

METHODS

Study Design

Monitoring is conducted in 250 randomly selected 6th field watersheds, each approximately 10,000-40,000 acres in size (Figure 1). To be included in the sample, a watershed must contain a minimum 25% federal ownership along the stream, based on the 1:100,000 stream layer. The program’s goal is to monitor 50 watersheds each year on a five-year rotation (Reeves et al. 2004). However, the program has yet to be fully funded, therefore we have sampled only 121 watersheds from 2002-2006. Data were collected for in-channel, riparian, and upslope

attributes. In-channel attributes were collected at randomly-selected sites (6 sites on average) within each watershed. Upslope and riparian data were collected from vegetation and roads layers using GIS. The evaluation of upslope and riparian conditions in watersheds was tailored to specific physiographic provinces. The physiographic boundaries used in this analysis were developed from those used in the aquatic ecosystem assessment, which were based on broadly drawn precipitation and geologic areas (FEMAT 1993).

Field Data Collection

Field data provide information on the physical habitat and the biota. Physical habitat indicators include: pool frequency, sinuosity, gradient, wood frequency, percent pool-tail fines, and substrate D₅₀. Water chemistry data were also collected. Biological indicators include: periphyton, benthic macroinvertebrates, aquatic and terrestrial amphibians, and fish.

Three types of surveys are conducted, with each type referring to a different point in time and a different purpose for the data collected. However, the data collection protocols were the same for all survey types. The survey types (with definitions) are as follows:

- Initial Surveys – These surveys were conducted at sites that the monitoring program had not previously surveyed. The sites were surveyed within a subset of the 250 randomly selected watersheds used to assess the success of the Northwest Forest Plan.
- Quality Assurance/Quality Control (QAQC) Surveys – These surveys were conducted at sites that were randomly selected from the initial surveys. The intent of these surveys was to determine the abilities of field crews to measure the same segment of a stream consistently. These surveys always occurred after the Initial Survey and were conducted by an independent crew. During the resample visit, only the start point of the survey was established. All other sampling was conducted in the same way as the original survey.
- Trend Surveys – These surveys were conducted at the previous year's QAQC sites. These sites were surveyed by a different field crew at each subsequent survey. The intent of these surveys is to assess trend in a subset of the 250 watersheds prior to completion of the full cycle of sampling.

For the initial surveys, eighty potential sampling sites were randomly chosen along the stream network in each watershed and identified with a GPS coordinate. In the field, sites were considered for sampling in numerical order, omitting sites that could not be sampled. The goal was to sample as many sites as possible within the watershed. However, because of logistical constraints, we usually sampled the first six to eight accessible sites. Typically, fewer sites were sampled in watersheds that required a lot of time traveling to remote locations. The only reasons that a site was not sampled was if it was located on private land or could not be accessed due to private land; it was located on a glacier or in a lake; it was not safely accessible; if more than 25 % of the stream channel was dry; the stream was too small to sample (less than 1 meter wetted width and 0.1 meters deep in riffle habitats); the stream was too large to physically sample (pools were too deep to wade, picking up pebbles on the bottom would require a wet suit, and wading across the stream was only possible in a few riffles); or travel time on foot to and from the site was greater than 4 hours.

The length of each site was approximately 20 times the bankfull width (using 2 m bankfull width categories) with minimum and maximum reach lengths of 160 and 480 m. Sampling was

conducted at 21 transects (11 major and 10 intermediate transects), equally-spaced along the length of the sample reach (Figure 2). We established the start point for sampling at the GPS coordinate and measured the reach upstream along the thalweg one transect at a time. The end point was established at the 21st transect location. Side channels were included in the survey only if they began and ended within the survey reach and the average bankfull width of the side channel was at least 20% of the bankfull width of the primary channel. We documented the start of the reach by recording the GPS coordinate with a Garmin GPS 12-map, taking a minimum of nine photos from the start point (facing left bank, downstream, right bank and upstream), and posting a marker near the start point. Photographs of the sample location and unique features were used in lieu of monuments in wilderness areas.

Physical Habitat

Bankfull widths, valley length, bed elevations were measured in each sample site using a laser rangefinder. We measured bankfull width at each of the eleven major transects and calculated average bankfull width of the reach based on these measurements (Table 2). Additional points were measured at the wetted edges and thalweg of major transects and at the thalweg of minor transects. Sinuosity was calculated as the length of the reach along the thalweg measured with a measuring tape, divided by the straight line distance between the thalweg at the start of the reach to the thalweg at the end of the reach, measured with the laser. Reach gradient was determined by the change in elevation of the left wetted edge at the bottom (transect A) to the top (transect K) of the reach, divided by the reach length.

The locations of each pool-tail crest, maximum pool depth and pool head were captured with the laser rangefinder. Pools were defined as being concave in profile laterally and longitudinally; bound by a head and a tail crest; occupies greater than 90% of the wetted channel width at any location within the pool; has length greater than its width; maximum depth at least 1.5 times the pool tail depth; and only including pools containing the thalweg. Pool measurements were used to calculate pool frequency and residual pool depths (Table 2). Residual pool depth is the elevation change from the thalweg at the pool tail crest to the deepest part of the pool.

Substrate particles for the D_{16} , D_{50} and D_{84} calculations were measured using a modification of the Environmental Protection Agency's Environmental Monitoring and Assessment Program substrate protocol (Peck et al. 1999). Five substrate particles were collected from each of the 21 transects at 10%, 30%, 50%, 70% and 90% of the distance across the bankfull channel. Each particle was measured along its intermediate axis with a meter stick. Percent fines (particles less than 2 mm diameter) were measured in the tails of scour pools as described by the USDA Forest Service Region 5 SCI protocol (1998). A 14 inch by 14 inch Klamath grid with 7 equally spaced horizontal and vertical partitions was used to count the number of intersections on top of substrate less than 2 mm and greater than 512 mm. Three grid measurements were taken in each pool tail at 25%, 50% and 75% of the distance across the wetted width, and 10% or one meter (whichever was less) of the pool length upstream of the pool tail crest. These measurements were converted to a percent and then averaged for the first 10 pools (Table 2).

The large wood protocol was adapted from the Oregon Department of Fish and Wildlife's Stream Habitat Surveys (Moore et al. 1999). Within each reach (main channel and side channels, if any), pieces of large wood were counted if they had a minimum length of 3 m, and

were at least 0.3 m in diameter at one third of the distance from the large end. Length and diameter were visually estimated for each piece. The length and diameter of the first 10 pieces encountered in the reach and every 5th piece thereafter was measured using a measuring tape so that estimates could be corrected. In addition, notes were made on the location of the wood relative to the channel, whether the piece was natural or artificial (part of a man-made structure), whether the piece was single, part of an accumulation (2-4 pieces touching) or part of a jam (5 or more pieces), and the percent of each piece of wood that would be submerged at bankfull flows.

Temperature, dissolved oxygen, pH, conductivity, and specific conductance measurements were collected at the upstream end of each sample site using a YSI 556 multi-probe meter, at five minute intervals for two hours. These measurements were averaged for each reach. Water temperature measurements were recorded hourly from June 1 until September 15 with continuous recording temperature loggers at the lowest point in the watershed on federal land. From these temperature data, the maximum seven-day average temperature was calculated.

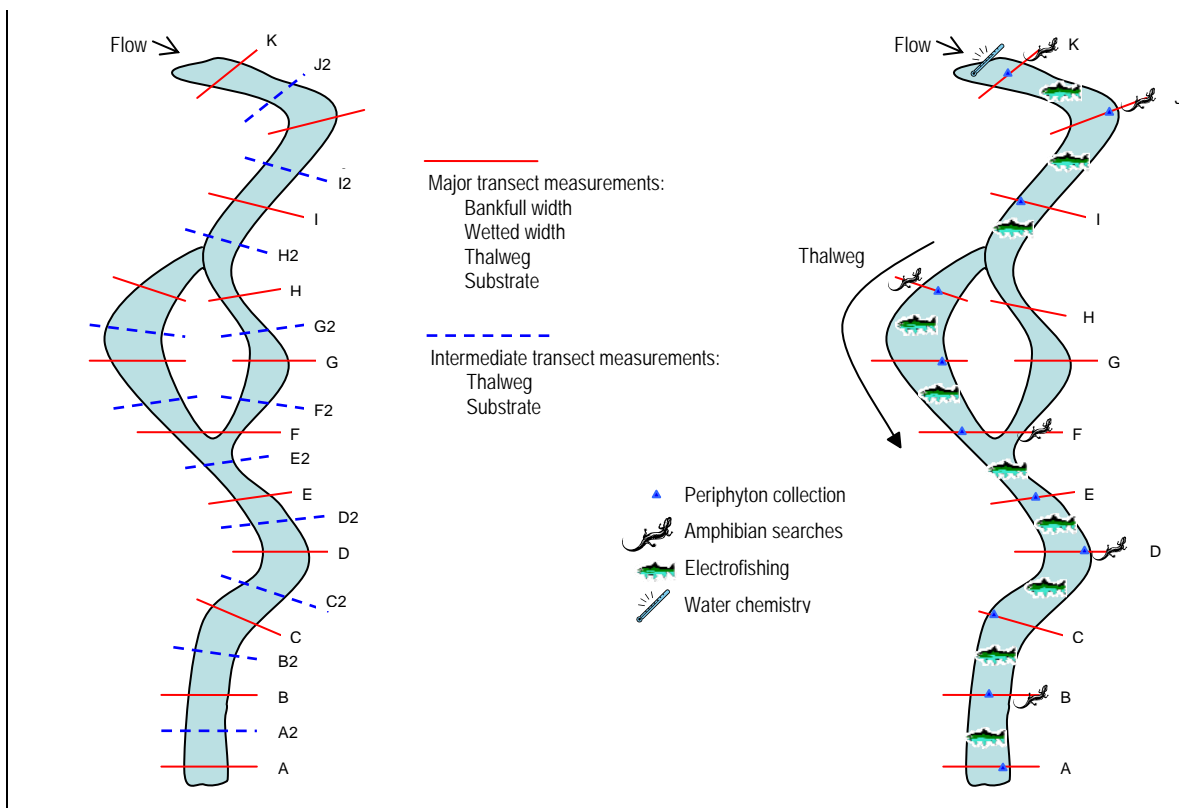


Figure 2. Overview of site layout and sampling strategy. The start point is established at the downstream end of the reach at transect A. Major and minor transects are equally spaced along the thalweg. Measurements and sampling conducted at each transect is outlined in the figure.

Table 2. Equations used to calculate physical channel attributes. Precision is the number of significant digits used in the calculation.

ATTRIBUTE	DEFINITION	EQUATION	PRECISION	# OF MEASUREMENTS
Average Bankfull Width	Average of the bankfull widths measured at the eleven major transects in the reach.	(Sum of BF widths) / Number of transects	0.1 m	11
Bankfull Width: Depth Ratio	Ratio of bankfull width to bankfull depth each channel cross-section.	Depth: Area of cross-section / BF width Width: BF width W:D = BF width / BF depth	1	1 width, 5 depth
Sinuosity	Reach length (measured along thalweg) divided by straight valley length (length from bottom to top of reach).	Reach Length / Valley length	0.1	1
Reach Gradient (% Slope)	Elevation change of substrate surface at the thalweg, from bottom to the top of the reach divided by the reach length (measured along the thalweg).	(Change in Elevation / Reach Length) * 100	0.1 %	1
Average Residual Pool Depth	Average of residual pool depths for all pools.	(Sum of (Pool Max Depth - Pool Tail Depth)) / Number of Pools	0.01 m	All qualifying pools, according to the AREMP protocol.
Pool Frequency	Number of pools per 100 m.	(# pools / reach length) * 100	0.001 m ⁻¹	All qualifying pools, according to the AREMP protocol.
Large Wood Frequency	Number of wood pieces greater than .3 m diameter and 3 m long, per 100 m.	(# pieces / reach length) * 100	0.001 m ⁻¹	All qualifying pieces, according to the AREMP protocol.
Percent PTC Fines	Percent surface fines measured 3 times, 10% or 1 m upstream of the tail crest of a pool.	Average of: (Sum of # Fines Measurements / (150-(sum of # non-measurements))) * 100	0.1 %	The first 10 qualifying pools, according to the AREMP protocol
D50 Pebble Count	D ₅₀ (mm) is the 50th percentile (median distribution) of the substrate particles measured.	Intermediate axis diameter of the median particle collected from particle counts.	1 mm	5 particles per transect on 21 transects.
D84 Pebble Count	D ₈₄ (mm) is the 84th percentile. 84% of the substrate particles measured are less than the size calculated.	Intermediate axis diameter of the particle for which 84% of the particles are smaller (84th percentile).	1 mm	5 particles per transect on 21 transects.
D16 Pebble Count	D ₁₆ (mm) is the 16th percentile. 16% of the substrate particles measured are less than the size calculated.	Intermediate axis diameter of the particle for which 16% of the particles are smaller (16th percentile).	1 mm	5 particles per transect on 21 transects.

Biological Sampling

The periphyton protocol used for field collection and lab analysis is the same as that outlined by Peck et al. (1999). At each of the eleven major transects, periphyton was removed from an assigned sampling location (left, center, or right bank), which alternated at each transect. All attached periphyton inside a 12 cm² area was removed by scrubbing for approximately 30-45 seconds with a toothbrush. Material clinging to the toothbrush was washed into a 55 ml bottle. One subsample from each transect was composited into a single sample for each reach. Samples were analyzed by Loren Bahls, Ph.D. in Helena, MT. Each sample was placed on a slide and at least 300 individuals were identified and enumerated for relative abundance assessments. All non-diatom taxa were identified to genus; diatoms were identified to species level.

Benthic macroinvertebrates were collected and analyzed using the protocol described by Hawkins et al. (2001). Using a kick net, we collected two subsamples at randomly-selected locations in each of the first four fast-water units encountered in each reach (8 subsamples total). All rocks larger than a golf ball within each 0.09 m² sample area were rubbed to remove attached organisms, and then placed outside the sampling area. The exposed areas of embedded rocks were also rubbed. Finally, the substrate within the sampling area was disturbed for approximately 30 seconds. The eight subsamples were decanted with a sieve, washbasin, and bucket to remove inorganic substrates, and invertebrates were composited into a single sample for each reach. Samples were sent to a laboratory where all insects were identified to the genus level (except Chironomidae, which were identified to subfamily).

At each site, fish and aquatic amphibians were sampled using a single pass with an electrofisher. The goal was to obtain a complete taxa list and species composition for each site within the watershed. All captured animals were identified and enumerated. Animals that were missed were also noted, however the information was not used in the analysis. Animals collected from 20% of the length of the reach were measured, and their condition was estimated using volumetric displacement. Snout-vent and total lengths were measured for all aquatic amphibians and fork length for each fish captured.

Time and area-constrained searches were conducted for terrestrial amphibians at each site within the watershed. At six of the major transects, searches began at the wetted edge and continued up the bank on either side of the stream, within 2 m of the wetted edge. Each search lasted five minutes (ten minutes total at each transect). During this time, searchers rolled over rocks and logs, and dug through leaves and soil. All captured terrestrial amphibians were identified, counted, measured for snout-vent and total length, and then returned to the area captured. The protocol used was adopted from Aquatic/Land Interaction Team at the PNW-FSL (Dede Olson, personal communication).

GIS Data Collection

Analyses of road and vegetation attributes were based on geographic information system (GIS) coverages. These analyses were tailored to physiographic provinces, which were based on broadly drawn precipitation and geologic areas (FEMAT 1993). Watershed boundaries used in the analysis were from the first draft of the 6th-field Hydrologic Unit Code boundaries developed in 2002. We used 1:24,000 densified stream layers from the Forest Service Region 6

Hydrography framework project. In the West Cascades Province, we defined riparian area by creating a 50-meter fixed buffer along both sides of all streams on the 1:24,000 stream layer.

Road Analysis

Road density and frequency of road-stream crossings were calculated using GIS coverages that were pieced together from Forest Service road and BLM ground transportation coverages. The Forest Service coverages, dated 2002, were obtained from each of the national forests in the Forest Plan area and clipped to the administrative boundaries of the forests. The BLM ground transportation coverage contains data from 1998 that cover all of the BLM districts and other non-BLM lands.

In the West Cascades Province, road densities in riparian areas were calculated for each watershed. The road layer was laid over the 50 m riparian buffer and riparian road density was calculated by dividing the miles of road within the riparian boundaries by the total stream miles. We overlaid road and 1:24,000 stream layers in each watershed and counted the number of road and stream intersections. Crossing frequency was expressed as the number of crossings per mile of stream. Forty-eight sample watersheds spread across the Plan area were inspected for potential erroneous crossings from digitizing errors. The percentage of suspected false crossings was less than two percent for the total sample.

Vegetation Analysis

The percentage of the watershed covered by urban or agricultural land, and conifer size and percentage of canopy cover in riparian areas were included in the monitoring plan's evaluation of watershed condition. Vegetation data were collected from coverages developed by the Interagency Vegetation Mapping Project version 3.0 that were updated using the vegetation change layer developed for the Northwest Forest Plan vegetation monitoring program (Moeur et al. 2005). These layers were built using Landsat Thematic Mapper remote sensing data. The coverages were clipped to watershed boundaries and the area covered by urban or agricultural land was calculated as a percentage of the total watershed area. The 50-m riparian buffer was used to calculate the percentage of forested riparian area containing conifers with diameter at breast height greater than 20 inches. To calculate forested riparian area, we subtracted non-forested areas, defined as areas incapable of producing trees (such as glaciers, lakes, lava beds or agricultural lands), from the total area within the riparian buffer.

Assessment of Watershed Condition

Decision support models were used to assess the condition of individual watersheds. These models are computer-based models that capture evaluation procedures and apply a consistent decision or evaluation process across time and space. Reeves et al. (2004) recommended using these models because they are transparent and easy to replicate. The transparent quality of the model facilitates explaining how the assessment was conducted.

Decision support models use data to evaluate a premise. For this analysis, we evaluate the premise that watersheds are in good condition. Data used in the assessment lend varying levels of support to that premise, ranging from full support to no support. We developed criteria to evaluate each attribute based on data and professional judgment. Data on individual attributes were compared to these criteria and given an evaluation score that ranges between +1 and -1, where +1 indicates full support and -1 indicates no support for the premise. Evaluation scores for the attributes were aggregated into an overall assessment of watershed condition. User-

defined rules produce an aggregated score weighted toward the resource with either the highest or lowest evaluation score, or a score can be based on the weighted or unweighted average of the indicator evaluation scores. Selection of the rules was based on professional judgment that relied on knowledge of the watersheds and ecological processes. In the models used in this analysis, evaluation scores were typically aggregated using either a weighted or unweighted average. Weights were assigned based on the experts' opinions about the relative importance of individual attributes in contributing to the condition of watersheds. In a few cases, an aggregated score weighted toward the lowest evaluation score was used to allow a single variable to override other variables.

A decision support model was built, refined, and peer-reviewed for each physiographic province to account for the ecological differences that exist between provinces. The workshops consisted of an informal group process through which local experts came to consensus on the model structure and evaluation criteria. After the workshops, models were built and run and the results were returned to the workshop participants. Participants compared the results of the model to their knowledge of the condition of the watersheds and suggested refinements to the model as necessary. Changes were made to the model and the results were re-evaluated.

MODEL DESCRIPTION AND INTERPRETATION

Watershed and reach condition scores are presented in the model output table in the watershed data summary document. These scores were calculated by evaluating individual attributes and then aggregating their evaluation scores.

How the Model Works

The West Cascades Province model includes an evaluation of both watershed and reach-scale attributes. The model hierarchically aggregates data from a number of attributes into broader indices of reach and watershed condition. For example, the reach condition score also serves as one component of the broader watershed condition score. In this case, the reach condition score used in the watershed model is the average of the evaluation scores of all the reaches in the watershed. A graphical depiction of the model structure for the West Cascades Province is presented in Figures 3 and 4. In this iteration, some model sections were "turned off" because the corresponding data were not available. These unused portions of the models are indicated in gray on the diagram.

The model begins by reading a set of data observations, which we call "attributes" for a watershed. These attributes are the right-most nodes in the model structure diagrams. For example, water temperature (maximum seven-day average) is an attribute of the watershed condition model. When the provincial experts constructed the model structure, they also developed evaluation criteria for each attribute. The attributes and evaluation criteria that make up the watershed and reach condition models are described in Tables 3 and 4.

The watershed model attributes column contains the attribute name, units of measure and qualifiers, if there are any. For example, temperature is evaluated differently in watersheds depending on whether or not bull trout are present. The data value and evaluation score columns show how the data values correspond to evaluated scores. The curve shape column gives a graphical depiction of the relationship, with data values represented on the x-axis and

corresponding evaluation scores on the y-axis (Table 3). The evaluation curves depict how each data value is scored on a scale from +1 to -1, according to its contribution toward overall watershed condition. As attribute data are read into the model, they are compared to the evaluation criteria to produce an evaluation score between +1 and -1. The source column gives the basis on which the curve was constructed, which is most often the professional judgment of workshop participants, but also includes datasets, published reports or standards.

For example, in the West Cascades Province, if there are no roads within the riparian area (riparian road density = 0), then the evaluation score would be +1 because it is at or less than the node-x value of 0; if road density was 0.1 miles of road per mile of stream or greater, the score would be -1; and if the density falls between 0 and 0.1, the attribute receives a score that is a linear interpolation between +1 and -1 (for example .05 would evaluate to 0). Note that there is an important difference between a data value of “zero” and “no data”. Data values of zero (as in the lower-slope road density example above) are compared to their evaluation curve in the same way as all other data values.

After each attribute datum is evaluated, the model aggregates the attribute evaluation scores together in a hierarchical fashion. The combined score is passed up to the next level in the model hierarchy where it is combined with results from other parts of the model (Figure 3). To assign levels of importance to different variables, the model uses two different operators to aggregate the evaluation scores: MIN, where it takes the minimum score from those being aggregated, and AVE, where it averages the scores. These functions reflect whether the attribute is a “limiting factor” type and the worst condition score determines the combined score (MIN), or a “partially compensatory” situation, where scores are all counted equally (AVE). In addition to operators, each node in the model can also be assigned a weight. For example, 70% of the weight could come from one attribute and 30% from another. In the West Cascades watershed condition model, none of the nodes were weighted.

Reach condition scores were determined in a similar fashion to watershed condition scores. Attribute data values were assigned evaluation scores which were aggregated using operators, and assigned weights to obtain an overall reach condition score (Figure 4).

How to Interpret the Assessment of Watershed Condition

The assessment of watershed condition table in the watershed data summary document presents the evaluation scores from the top down, in an outline format. The indented attributes represent the contributing attributes with their data values and corresponding evaluation scores. At each higher level of the outline, the aggregation of the contributing evaluation scores is displayed, consistent with Figure 3. Reach condition scores for each of the sites that were surveyed in the watershed are presented in the table below with the sites listed from left to right. The tab left of the model output tab in the excel document contains a data dictionary explaining each of the attributes that were evaluated in the model, listed in the same order as on the Watershed Condition table.

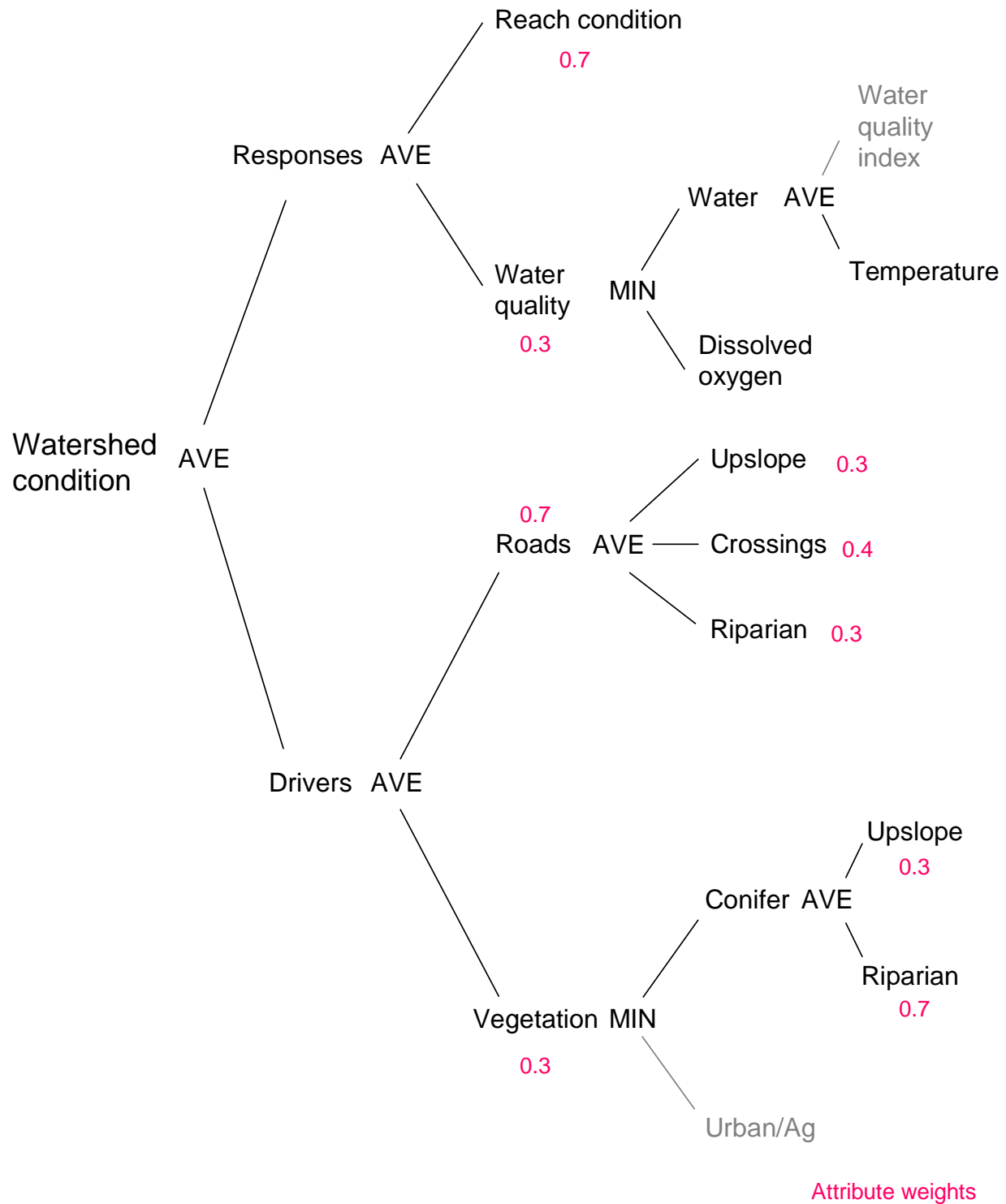
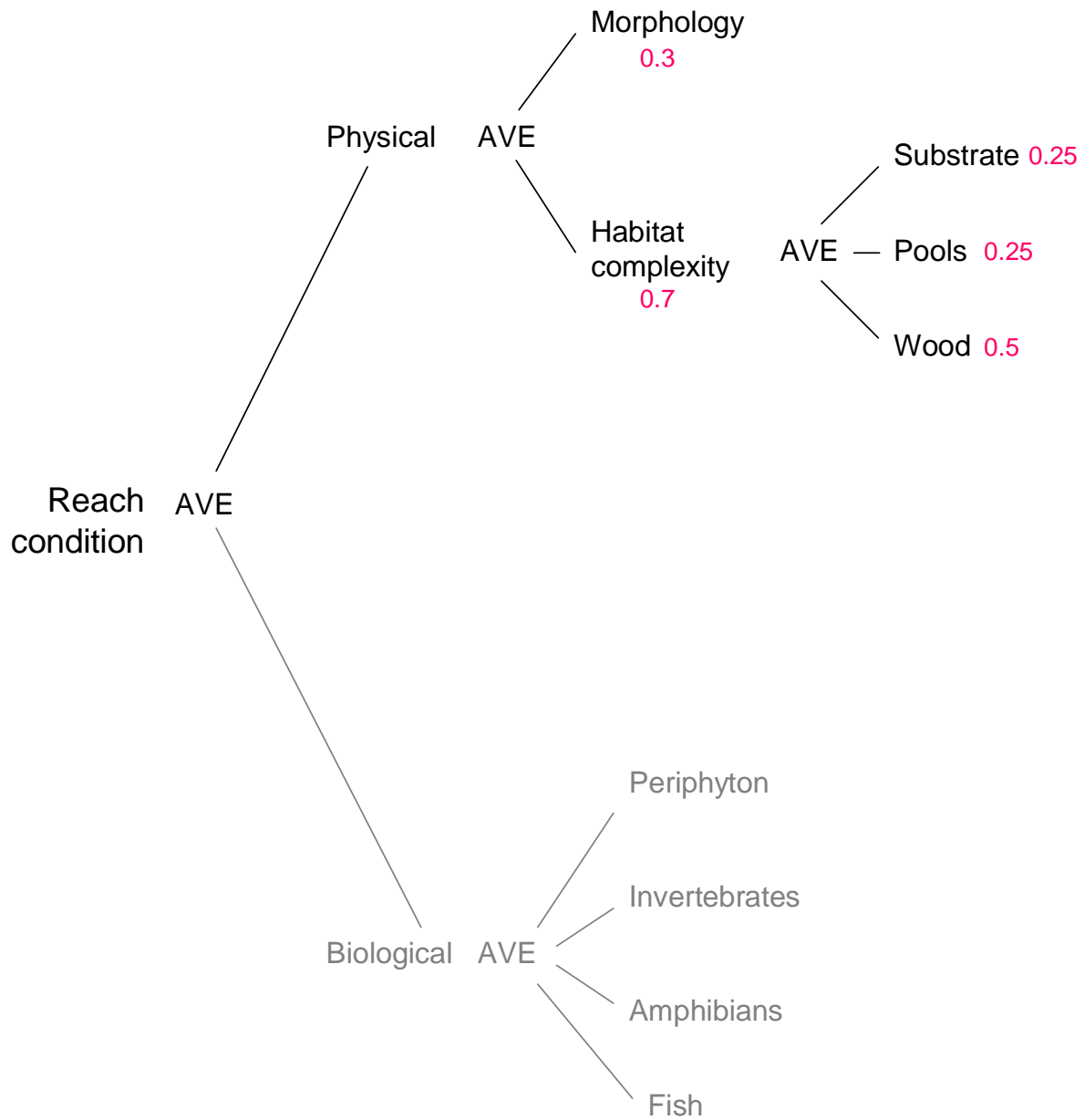


Figure 3. Graphical depiction of the watershed model structure for the West Cascades Province. The right-most nodes in the diagram represent watershed attributes that are evaluated and given an evaluation score. Evaluation scores are aggregated using the operators and weights depicted on the diagram to calculate an overall watershed condition score.



Attribute weights

Figure 4. Graphical depiction of the reach model structure for the West Cascades Province. The right-most nodes in the diagram represent reach attributes that are evaluated and given an evaluation score. Evaluation scores are aggregated using the operators and weights depicted on the diagram to calculate an overall watershed condition score. Reach condition scores are an attribute of the watershed condition model.

Table 3. Watershed model attributes and evaluation criteria for the West Cascades Province.


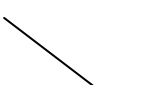
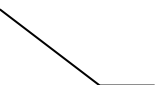
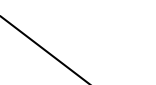
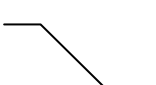
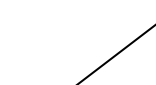


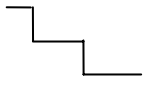
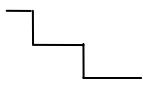
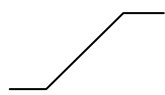


Watershed model attributes	Data value	Evaluation score	Curve shape	Source
	Node x-value	Node y-value		
High-slope road density slope >50% mi road / mi ² watershed	0 0.5	1 -1		AREMP Workshop 5/22/03
Upslope road density mi road / mi ² watershed	0 4	1 -1		Dose & Roper 1993 AREMP Workshop 5/22/03
Riparian road density mi road / mi stream 50m buffer	0 0.1	1 -1		AREMP Workshop 7/1/04
Road crossing frequency # crossings / mi stream	0 1.75	1 -1		AREMP Workshop 7/1/04 WNF ave 1.44 (1:24k) MHNF ave 0.8
Upslope vegetation Small conifer cover % area with conifers <10" dbh	10 40	1 -1		AREMP Workshop 5/22/03
Riparian vegetation Large conifer cover % area with conifers ≥20" dbh 60m buffer	60 100	-1 1		AREMP Workshop 7/1/04 dbh from wildlife handbook Dose & Roper pub on harvest/roads vs condition >30% ws impacted
Water temperature maximum 7-day average °C	16 18 23	1 0 -1		AREMP Workshop 5/22/03
Dissolved oxygen % saturation or mg/L	< 50% ≥ 50% < 4 ≥ 4	-1 1 -1 1		AREMP Workshop 5/22/03

Table 4. Reach model attributes and evaluation criteria for the West Cascades Province.

Reach Model Attributes	Data value Node x-value	Evaluation score Node y-value	Curve shape	Source
Morphology Slope Entrenchment ratio Sinuosity Bankfull width: depth				Professional judgment
				Use to determine Rosgen stream type. If D,F,G channel then -1, otherwise +1
Pool frequency # bankfull widths per pool				
≤ 3% slope	< 5 5 7 > 7	1 0 0 -1		Montgomery and Buffington (1993)
> 3% slope	<1 1 4 >4	1 0 0 -1		Montgomery and Buffington (1993)
Wood frequency # pieces per 100 m	1 4	-1 1		Professional Judgment
Substrate D50 mm ≤ 5% slope	40 60 140 200	-1 1 1 -1		AREMP Workshop 5/22/03
> 5% slope	40 60 200 500	-1 1 1 -1		Professional Judgment

RESULTS

Watershed condition scores are the aggregate of all of the road, vegetation, and in-channel attributes collected. These scores range from -0.4 to 1 across the area encompassed by the Plan. In the West Cascades Province, watershed condition scores ranged from -0.5 to 0.5 (Figure 5).

Road condition scores (the aggregate of riparian road density and road crossing frequency) ranged from -1 to 1 across the Plan area and in the West Cascades Province (Figure 6).

Frequency of road crossings ranged from 0 – 2.9 crossings per mi of stream in the province (Figure 7). The distribution of riparian road densities in the West Cascades Province was consistent with that across the Plan area (Figure 8). Riparian road density ranged from 0.0 to 0.41 mi. of road per mi. of stream.

Vegetation condition scores, which consist of the evaluation of riparian vegetation and the percentage of the watershed in urban and agricultural land use, ranged from -1 to 1 in the Plan area and -1 to 0.6 in the West Cascades Province (Figure 9). The range of riparian areas in the 6-th fields that contained conifers greater than 20 inches in diameter at breast height was similar in the Plan area (0-90 %) and the West Cascades Province (8-80%; Figure 10).

In-channel conditions in the West Cascades province were consistent with conditions across the Plan area. Distribution of wood and pool frequencies in sample reaches in the West Cascades are consistent with those across the Plan area (Figures 13, 14).

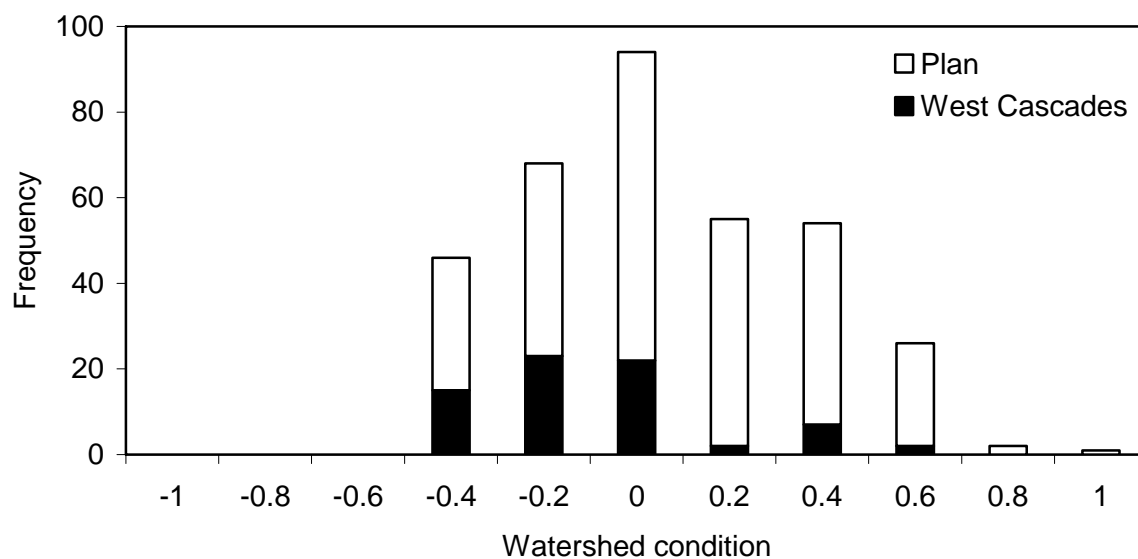


Figure 5. Distribution of watershed condition scores for the West Cascades Province and the Northwest Forest Plan area.

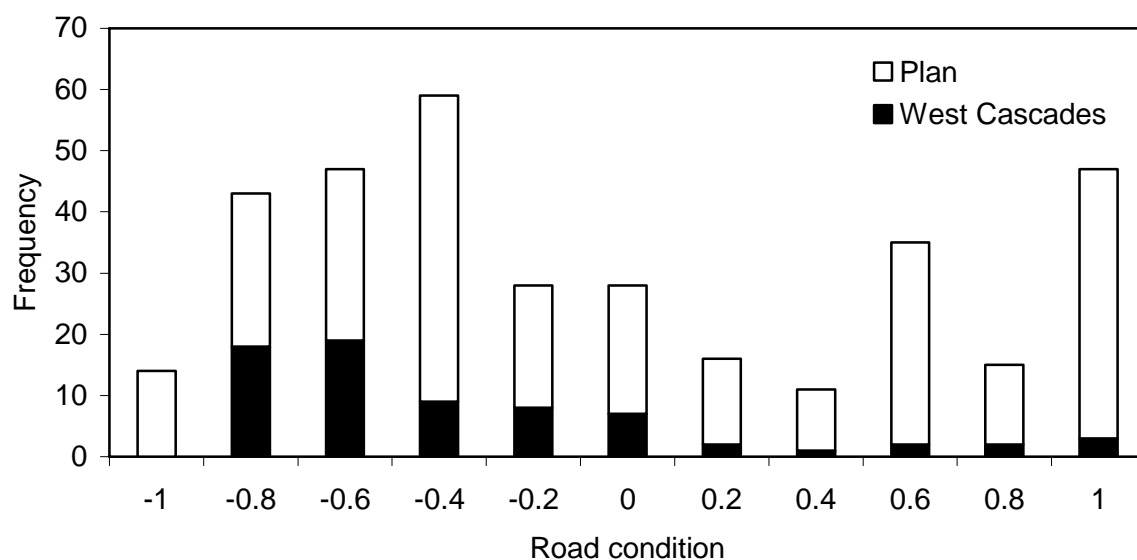


Figure 6. Distribution of road condition scores for the West Cascades Province and the Northwest Forest Plan area.

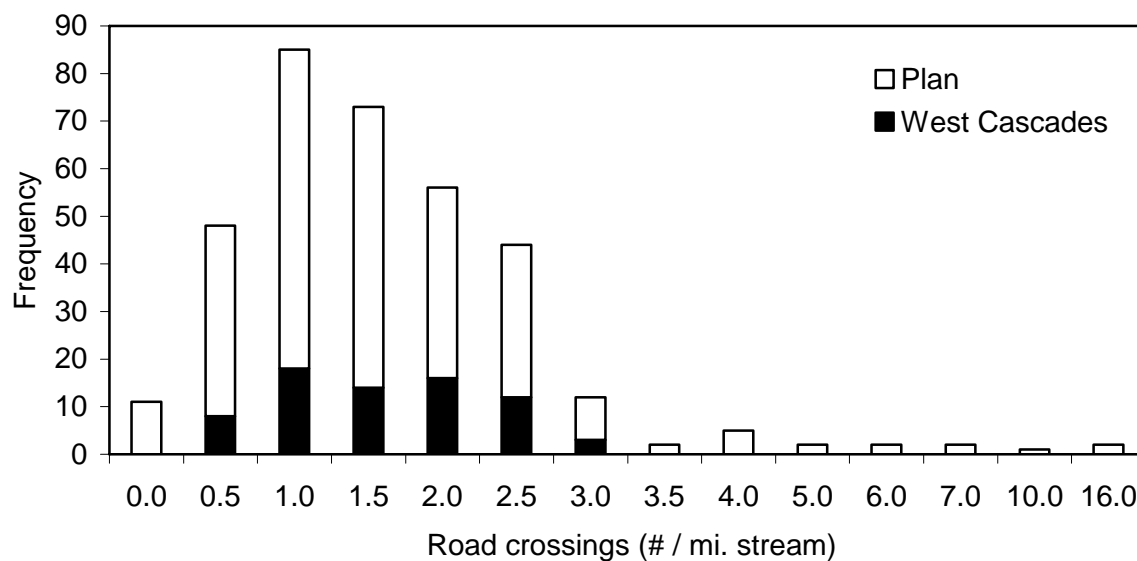


Figure 7. Distribution of road crossing frequencies in 6th-field HUCCs in the West Cascades Province and the Northwest Forest Plan area.

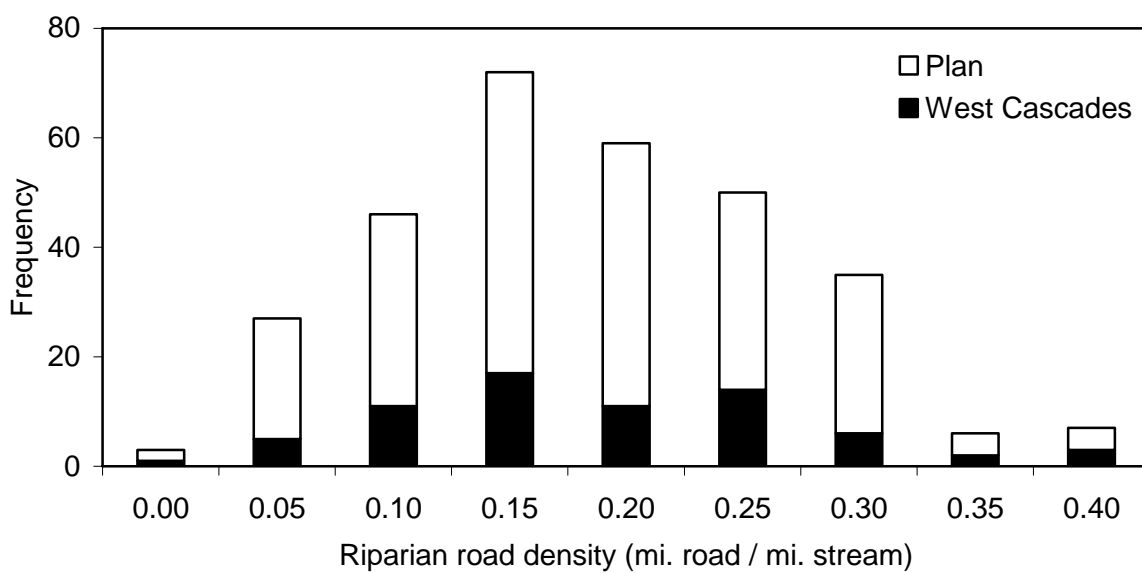


Figure 8. Distribution of riparian road densities in 6th-field HUCS in the West Cascades Province and the Northwest Forest Plan area.

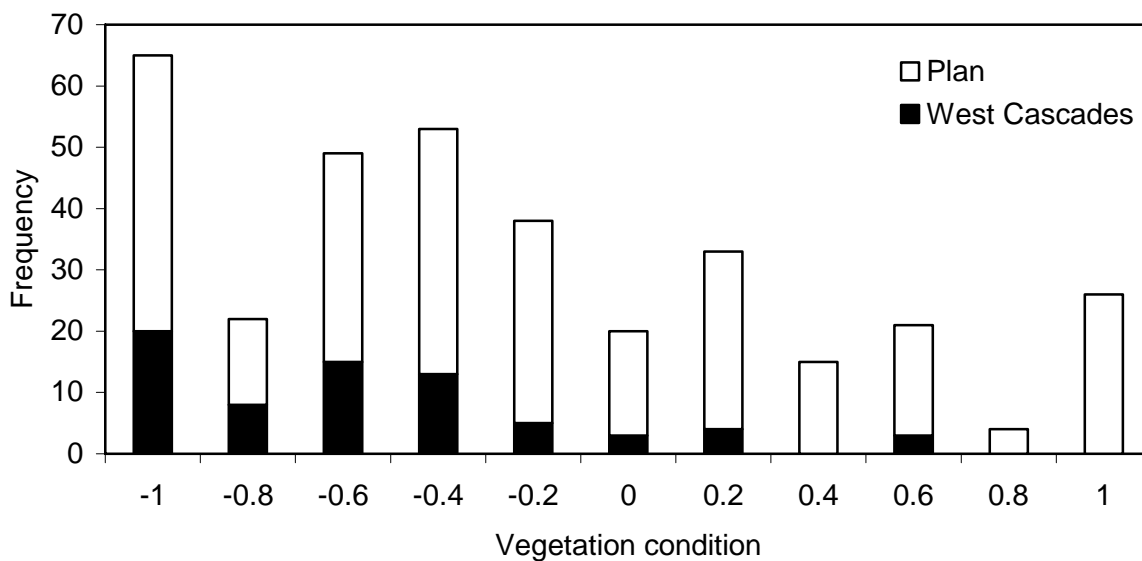


Figure 9. Distribution of vegetation condition scores in 6th-field HUCS in the West Cascades Province and the Northwest Forest Plan area.

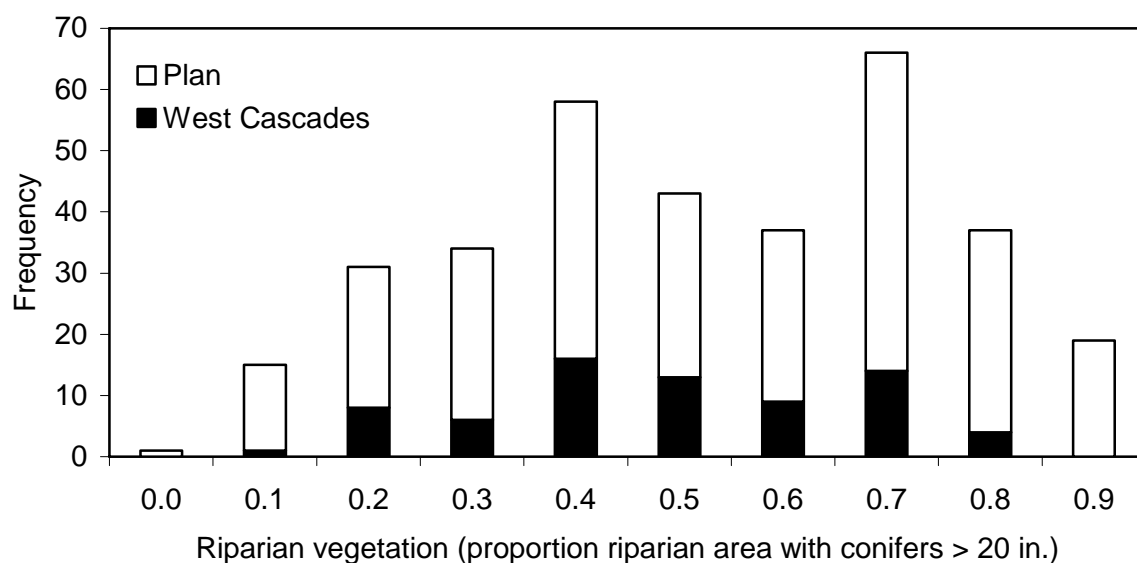


Figure 10. Distribution of riparian vegetation conditions (proportion of the riparian area with conifers greater than 20 inches in diameter at breast height) in 6th-field HUICS in the West Cascades Province and the Northwest Forest Plan area.

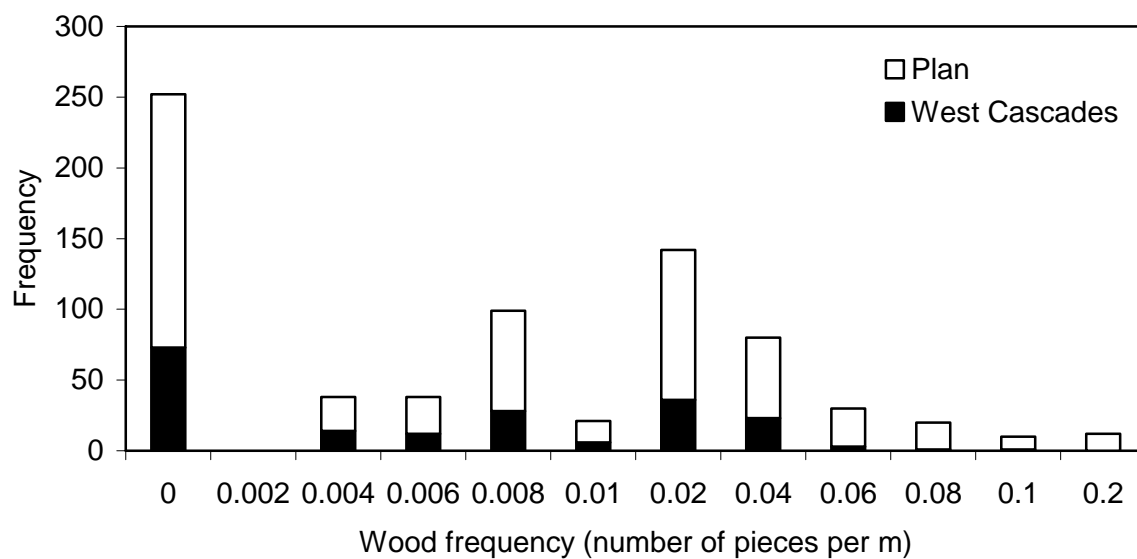


Figure 11. Distribution of wood frequencies in stream reaches in the West Cascades Province and the Northwest Forest Plan area.

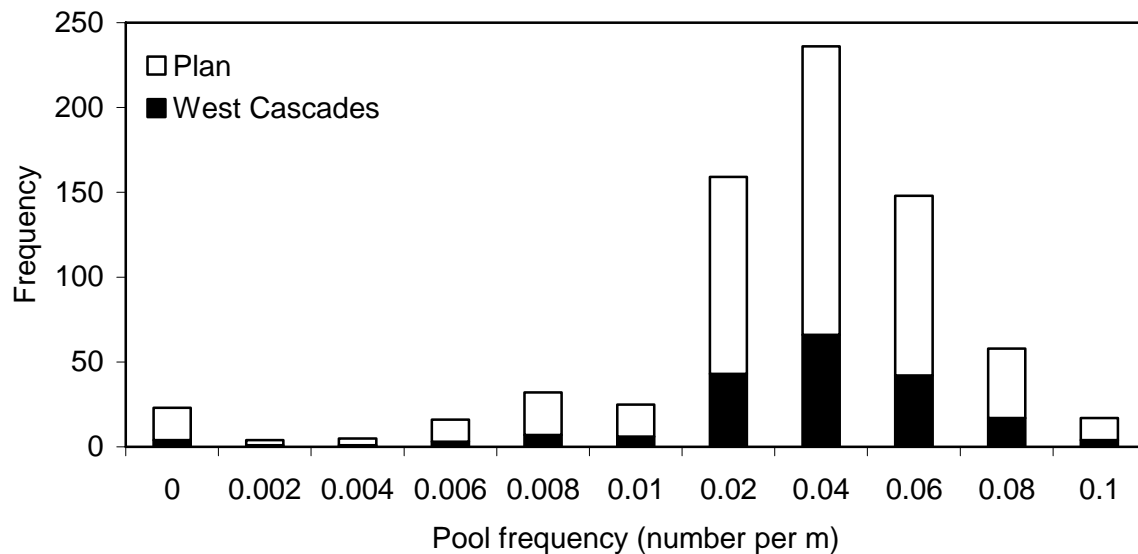


Figure 12. Distribution of pool frequencies in stream reaches in the West Cascades Province and the Northwest Forest Plan area.

Quality Assurance/ Quality Control

The Quality Assurance Program (QAP) report presents six years (2001 – 2006) of results for the QAP. This report focuses both on the ability of crews to conduct surveys as well non-analytical results of the QAP. Crew surveys were evaluated both with the signal to noise ratio (S:N) and plots of initial surveys against secondary surveys. The former technique is designed to address the issue of detecting trend given the impacts of crews on measurements, while the later focuses on how well two crews measure attributes at the same site. Non-analytical information captured in the report address issues of data quality control and corrective measures used during data acquisition. Key findings of the report to date are:

- Attributes were judged on the number of years (of six) that they met or exceeded acceptable levels. For trend and consistency, 50 % of the attributes met the indicator criteria at least three of the six years (see Table 5 for discussion).
- The QA program has served the intended purpose of determining how well crews do at deriving the same answer for consistent attribute measurement.
- The QA program has had the unintended consequence of demonstrating several protocols' inability to detect change.
- The results of the analyses indicate that time (across years), which is confounded by annual changes in the field protocols, has an impact on the results of remeasurements.
- The QA program is successful at cleaning the field data and accounting for the errors present.

Table 5. Rating of field protocol attributes with respect to both trend and consistency. For trend, the number of years (of six) that the calculated signal to noise ratio (an indicator of ability to detect trend) met or exceeded a value of four. For consistency, the number of years (of six) that the calculated slope of the line between initial and secondary surveys (within year) was not significantly different than one. Good, fair, and poor represent 5-6 years, 3-4 years, and 0-2 years of the attribute meeting or exceeding the indicator value.

ATTRIBUTE	Overall trend rating	Overall consistency rating
average Bankfull width	Fair	Poor
average Bankfull depth	Poor	Fair
average Bankfull W:D	Poor	Fair
Gradient	Fair	Good
Sinuosity	Poor	Fair
D50	Poor	Fair
D50 without bedrock	Poor	Poor
% Pool tail crest fines	Good	Poor
Wood pieces	Good	Poor
Number of pools	Good	Poor
Residual pool depth	Poor	Poor
Dissolved oxygen	Fair	Poor
Conductivity	Good	Fair
pH	Poor	Fair
Percent salmonids	Good	Fair
Shannon diversity index	Poor	Poor
Species evenness	Poor	Poor

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